(1) For the extrusion calculations, what is being regressed – what is the independent variable for the regression and what is the dependent variable? What are the actual parameters being regressed (NOT m and n)?

\[ \ln(Q/Q_0) \text{ – dependent; } \ln(\Delta P) \text{ – independent.} \]

Actual parameters – since you divided by \(Q_0\), the intercept will be: \(-\frac{1}{n}\ln(\Delta P_0)\). This intercept is then put in terms of \(m, n\) using the formula in the lab writeup.

(2) Show the regression for \(m\) and \(n\) for all the data taken in the lab – not just your own. Share your data among yourselves so that you have enough data to regress.

An example sheet is attached.

(3) What is the formula for \(T\)-rise at the wall, in words? What assumptions did I make in deriving this formula?

\[ \frac{Q}{V} = \tau \dot{\gamma} \text{ so } \Delta T_{\text{wall}} = \frac{Q_{\text{wall}}}{m \, C_P} = \frac{V \, (\tau \dot{\gamma})_{\text{wall}}}{m \, C_P}, \text{ where } m \text{ is the mass flow rate, and } V \text{ is volume.} \]

(4) The solution of the stress equations for \(Z\)-flow (axial flow) in a cylindrical die is:

\[ \tau_{rz} = \left(\frac{\Delta P}{L}\right) \left(\frac{r}{2}\right) \]

When coupled with the power-law fluid equation the solution for \(Q\) is:

\[ Q = (\dot{\gamma}_\text{at wall}) \left[\frac{n \, \pi \, R^3}{(1 + 3n)}\right] \]

In this \(T\) region, a 10°C rise in \(T\) decreases “\(m\)” by 8% but does not change “\(n\)”. Using the largest \(\Delta P\) we measured, calculate the flow rate (\(Q\)) we would expect at 20°C higher than we ran in the experiment.

\[ \frac{Q_2}{Q_1} = (\dot{\gamma}_\text{at wall})_2/(\dot{\gamma}_\text{at wall})_1. \text{ Then using the relation for (\dot{\gamma} \text{ at wall}), if } n = 2.66 \text{ (e.g.), since } m_2 = 0.84 \, m_1 \]

\[ Q_2/Q_1 = [1/(0.84 \, m_1)]^{2.66} / [1/m]^{2.66} = 1.6 \]

(5) Using your rheometer data for toothpaste, compute (at 0.1, 1 and 10 Hz) the maximum shear strains in %, the Maxwellian relaxation times, and the
dynamic viscosities. If we use the period of the harmonic motion to help us estimate the shear strain rates, compare the dynamic to the shear viscosities at the same shear rates. Does there appear to be a relationship between the two? If so, what is the relationship?

See attached example sheet. The formulas used are:

\[ f = \frac{\omega}{2\pi} = \text{frequency} \]

\[ G^* = (G'^2 + G''^2)^{0.5} = \text{complex modulus} \]

\[ G^* = \text{max. stress}/\text{max. strain} \text{, solve for max. strain } (\varepsilon_{\text{max}}) \]

\[ G''/G' = 1/(\omega \tau) \text{ for a single Maxwell element, solve for } \tau \]

\[ \eta' = \text{dynamic viscosity} = G''/\omega \text{, the answer will be in poise } [g/(cm*s)] \]

Shear strain rate \~ \frac{(2)(\varepsilon_{\text{max}})\text{/period}}{2(\varepsilon_{\text{max}})(f)}

Both dynamic and shear viscosity decrease as we increase the shear rate. But the dynamic viscosity is far more sensitive to the shear rate – it is nonlinear. This means that we are becoming more like an elastic solid while still retaining a high viscosity.